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Climate change impact on ocean carbon uptake CMIP5 in Earth System Models

J. Schwinger (1), J. Tjiputra (1), C. Heinze (1), J. Christian (2), L. Bopp (3), M. Gehlen (3), T. Ilyina (4), C. Jones (5), J. Segschneider (4), R. Séférian (3), and I. Totterdell (5)

(1) University of Bergen, Geophysical Institute & Bjerknes Centre for Climate Research, Bergen, Norway (jorg.schwinger@gfi.uib.no), (2) Canadian Centre for Climate Modelling and Analysis, University of Victoria, Canada, (3) Laboratoire des Sciences du Climat et de l'Environnement, Gif sur Yvette, France, (4) Max Planck Institute for Meteorology, Hamburg, Germany, (5) Met Office Hadley Centre, Exeter, UK

Uptake of carbon by the ocean is increasing with rising anthropogenic CO_2 emissions to the atmosphere. In addition also climate change and respectively induced changes in ocean circulation, seawater hydrography (temperature, salinity), and marine biogeochemistry can induce changes in the marine inorganic carbon system with implications for CO_2 uptake, pH, and carbonate saturation. It has been a common assumption that the total carbon uptake can be expressed as the sum of a portion due to climate change only, and a portion due to rising atmospheric CO_2.

In this study we analyse simulations of a suite of state of the art earth system models with fully coupled carbon cycle modules in order to separate the impact of rising CO_2 in the atmosphere and the impact of climate change on ocean carbon uptake and ocean acidification. The models have run a number of synthetic experiments, as defined for the Coupled Model Intercomparison Project Phase 5 (CMIP5), which are used for this analysis. A fully coupled simulation with a prescribed 1% increase of atmospheric CO_2 per year serves as a baseline, while in two additional simulations the increase in CO_2 is “seen” only by the radiation code of the model or the biogeochemistry modules, respectively. The impacts of these different settings on the ocean physics, the inorganic CO_2 chemistry as well as the impact on the biological part of the ocean carbon cycle are analysed. Model results show, that the total ocean uptake from the "rising CO_2 but no warming" runs and the "warming under constant CO_2" CMIP5 runs do not add up linearly to yield the carbon uptake of the fully coupled run. The difference, i.e. the degree of non-linearity, is of the same order of magnitude, or larger for some models, than the climate change impact itself. Here, we disentangle the contributions of the non-linear ocean carbon chemistry and biology as well as the contribution of physical climate change to this behaviour.